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A STUDY OF STRATOSPHERIC DISCHARGES

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Block 20, Abstract, Continued

and New Mexico failed to indicate anomalous spectra that might characterize low pressure discharges in the stratosphere. Photographs, spectral observations, and field change measurements were made from a U-2 aircraft looking down on an active thunderstorm suggesting that lightning discharges can frequently be produced that will traverse stratospheric air.

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We are happy to acknowledge the cooperation of NASA, who made possible the use of one of their U-2 aircraft. We are grateful for the cooperation of New Mexico Institute of Mining and Technolgoey, which provided facilities for lightning observations from Langmuir Laboratory. We acknowledge with thanks the support and many helpful suggestions of Dr. Edmond Dewan of the Air Force Geophysics Laboratory.

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A STUDY OF STRATOSPHERIC DISCHARGES

Final Report

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INTRODUCTION

There can be no doubt that most thunderstorm electrical discharges originate and propagate entirely in the troposphere. There is evidence, however, from ground observers and from airplane pilots that some of the electrical discharges can propagate into stratospheric air. As was originally suggested by C. T. R. Wilson, it is possible that there is a theoretical basis for believing that lightning-produced electric field changes in unusually tall thunderstorms may initiate dielectric breakdown, probably of a glow discharge character, some distance above the tropopause.

In order to obtain more information on the occurrence of such discharges and to learn more of their character, we have carried out field observations during the past two years. Ground based measurements involving photography and spectroscopic measurements of thunderstorms have been carried out

from observations at Albany, New York, and at Langmuir Laboratory on Mt. Baldy near Socorro, New Mexico. Through the cooperation of NASA, we have been able to instrument one of their U-2 aircraft and to obtain electrical and optical data looking down upon thunderstorms from an altitude of 65,000 feet.

OBSERVATIONS

We have obtained spectral observations from the ground of thunderstorms in New York State and in New Mexico, but thus far we have not been able to document any discharges occurring or extending into the stratosphere, either with our cameras or with the spectroscope. We have, however, obtained an interesting series of observations looking down from a U-2 aircraft on a vigorous nocturnal thunderstorm occurring in Arkansas on May 16, 1980. Figures 1 and 2 show the appearance of the thundercloud illuminated from within and without by lightning. In both pictures 1 and 2 lightning channels are clearly visible showing that the discharge was taking place in the upper part of the cloud, possibly and indeed probably above the level of the tropopause. Figure 3 is an enlarged view of lightning spectra obtained with a grating over the camera lens.

Although final detailed analysis of these observations is not yet complete, it is possible to make some generalizations about what is taking place.

DISCUSSION

Photographs of intense thunderstorms looking down from an orbiting satellite or a U-2 show that sharp cauliflower-like convective turrets, presumably because of their very intense updrafts, penetrate distances of several kilometers into the stable stratospheric air. Due to adiabatic cooling, the turrets are much colder than their stratospheric environment, and when their upward momentum has been dissipated, they fall back down to, and presumably below, the tropopause. Although these turrets are not uniform, smooth domes, photographs taken from above and from the side give every impression that most, if not all, of the cloud mass in the penetrative turret has risen well above the anvil at the tropopause. Infrared measurements made from the satellite indicating that the temperature of the air in these clouds can drop far below the temperature of the stratosphere are a good indication that most, if not all, of the penetrative turret is at levels above the tropopause.

When photographs taken at night looking down from the U-2 show segments of a lightning channel, there can be no question that this channel is above at least a portion of the penetrative tower. Since in some photographs, such as Figure 1, portions of the channel are obviously obscured by cloud, it is apparent that here a portion of the lightning channel lies buried within the convective cauliflower structure. Until stereo photographs are available from which the depths of the folds in the cauliflower structure

can be calculated, it will not be possible to say with certainty whether the level of these lightning segments lies above or below the tropopause.

Even if these segments of lightning channel are at elevations well above the tropopause, it is quite conceivable that any oxides of nitrogen or other chemical products they generate may be carried down into the cloud by downdrafts into the folds so that these products could not be expected to mix into the stratosphere.

Figure 2 shows lightning channels somewhat different from that illustrated in Figure 1 in that they are much longer, of the order of kilometers, and that they show branching. This picture indicates that the lightning channels in clear air have a horizontal extent in two dimensions of the order of several kilometers. Since this lightning structure appears to be in the foreground above a convective cloud structure, there appears good reason to believe that the discharge may be in stratospheric air. Although downdrafts may well exist in the stratosphere carrying stratospheric air down below the tropopause, adiabatic warming that occurs makes this appear unlikely that this could occur over an area this big. We, therefore, are of the opinion that in situations such as this, lightning probably deposits chemical products into the stratosphere that will remain to play a part in its chemistry.

So far as we are aware, there are very few photographs of lightning or lightning-illuminated clouds taken from satellites. Those pictures that we have seen were taken with a hand-held camera and long time exposures during photography of aurora. The photographic images are so blurred, it is impossible to determine whether the lightning was within the cloud or above the cloud.

DMSP images show bright, horizontal streaks caused by a flux of radiation undoubtedly originating from lightning, but the definition of the optical scanner is so large, it is impossible to tell whether the light came directly from the lightning channel or whether the light was diffused as a result of internal scattering within the cloud. Because light from lightning is not significantly absorbed when it passes through a cloud, as much as 10 percent of the radiation originating from the lightning can escape through a cloud thickness of the order of 5 km. Because the energy emitted by a lightning discharge varies greatly from one flash to another, it is not possible to tell from the amount of radiation received whether the lightning channel is above or some distance within the cloud.

Since we presently have no quantitative information relating the length of lightning channel above the cloud to that within it, it is not possible to make even order of magnitude guesses concerning the rate of injection of NO_x into the stratosphere.

At present, we cannot use this spectrum to identify the discharge altitude. In the future, however, we believe that O_2 absorption bands in the near infrared may be used to estimate the flash altitude.

We have obtained the meteorological soundings from several cities near the evening thunderstorms and for times within a few hours of the lightning. It appears that the U-2 pilot's estimate of the cloud-top height was below the tropopause, but we are still checking this. We have not yet verified the cloud-top height by the soundings; this is part of our current analyses.

Photo densitometer measurements may provide useful information concerning the relative intensities of spectral lines when they appear in these photographs. In those cases where multiple images resulting from film motion occur between strokes, it may be interesting to determine the relative intensities of the strokes. Such densitometric determinations will be made.

We believe that the pulses produced by illumination falling on our calibrated photocell will be a far easier and more meaningful basis for estimating the total energy of these discharges than might be obtained from photometric measurements made on the film with the big uncertainties that exist about the sensitivity of the emulsion.

CONCLUSIONS

The fact that even in the course of a large number of ground observations of thunderstorms in New York and New Mexico we have failed to document either lightning or electrical discharges in the stratosphere indicates that this is a phenomenon that is not easily observed from the ground. That our first and only observation of a nocturnal storm looking down on it from above shows some lightning discharges in the top most part of the cloud, probably well above the troposphere, suggests that observations of stratospheric lightning can best be made from high altitude looking down upon the cloud. In future observations to be carried out this summer from a U-2 aircraft and from the second space shuttle flight, we hope to document and characterize further observations of stratospheric electrical discharges. In addition, we feel that it may be worth exploring the possibilities of photographing lightning with conventional cameras or with video television apparatus flown above clouds on high altitude balloons.

FIGURE CAPTIONS

FIGURE 1 Lightning channel less than 1 km long probably occurring in the cusp between two cumuliiform structures.

FIGURE 2 Two-dimensional lightning channel structure several kilometers long, clearly above some portions of penetrative top, probably above the tropopause.

FIGURE 3 Enlarged view of lightning spectrum obtained from U-2 with a camera equipped with grating.





